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IS 14901 (Part 3) : 2001
IEC 747-3 (1985)
[Superseding IS 3700 (Part 2) : 1972,
IS 3700 (Part 8) : 1970, IS 3715 (Part 2) : 1971,
IS 4400 (Part 2) : 1967 and IS 4400 (Part 8) : 1970]

भारतीय मानक

अर्द्धचालक युक्तियाँ — विविक्त युक्तियाँ एवं समाकलित परिपथ

भाग 3 सिगनल (स्विचिंग समावेशित) तथा नियंत्रक डायोड

Indian Standard

SEMICONDUCTOR DEVICES — DISCRETE DEVICES AND INTEGRATED CIRCUITS

PART 3 SIGNAL (INCLUDING SWITCHING) AND REGULATOR DIODES

ICS 31.080.10

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

January 2001

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Semiconductor Devices and Integrated Circuits Sectional Committee, LTD 10

NATIONAL FOREWORD

This Indian Standard (Part 3) which is identical with IEC 747-3 (1985) 'Semiconductor devices — Discrete devices — Part 3: Signal (including switching) and regulator diodes' including Amendment 1 (1991) and Amendment 2 (1993) issued by the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on the recommendation of the Semiconductor Devices and Integrated Circuits Sectional Committee and approval of the Electronics and Telecommunication Division Council.

This standard (Part 3) covers the terminology and letter symbols, essential ratings and characteristics, methods of measurements, and electric endurance tests for signal (including switching) diodes, voltage-reference diodes, voltage-regulator diodes and current-regulator diodes.

The object of this series of standards is to specify adequately the properties of the device for the intended application and to facilitate comparison and choice between similar products.

Hitherto, IS 3700, IS 3715 and IS 4400 series, based on IEC 147 series of standards, covered essential ratings and characteristics, letter symbols and methods of measurements of semiconductor devices respectively. However, IEC 147 series has been superseded by IEC 747 series. The present series of standards has been brought out to consolidate the provisions of IS 3700, IS 3715 and IS 4400 series and align it with the latest version of IEC 747 series.

This standard (Part 3) supersedes IS 3700 (Part 2) : 1972 'Essential rating and characteristics of semiconductor devices: Part 2 Low power signal diodes', IS 3700 (Part 8) : 1970 'Essential rating and characteristics of semiconductor devices: Part 8 Voltage-regulator and voltage-reference diodes', IS 3715 (Part 2) : 1971 'Letter symbols for semiconductor devices: Part 2 Diodes', IS 4400 (Part 2) : 1967 'Methods of measurements on semiconductor devices: Part 2 Low power signal diodes' and IS 4400 (Part 8) : 1970 'Methods of measurements on semiconductor devices: Part 8 Voltage-regulator and voltage-reference diodes'.

The text of the IEC has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
b) Comma (,) has been used as a decimal marker while in Indian Standards the current practice is to use a point (.) as the decimal marker.

CROSS REFERENCES

In the adopted standard, reference appears to the following International Standards for which Indian Standards also exists. The corresponding Indian Standards which is to be substituted in its place is listed below along with its degree of equivalence for the edition indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60747-1 (1983) Semiconductor devices — Discrete devices and integrated circuits — Part 1: General	IS 14901 (Part 1) : 2000 Semiconductor devices — Discrete devices and integrated circuits: Part 1 General	Identical

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

CONTENTS

Page

CHAPTER I: GENERAL

Clause

1. Introductory note 3
2. Purpose 3
3. Letter symbols 3

CHAPTER II: TERMINOLOGY AND LETTER SYMBOLS

SECTION ONE — SIGNAL DIODES (INCLUDING SWITCHING DIODES)

1. General terms 4
2. Terms related to ratings and characteristics 4
3. Letter symbols 7

SECTION TWO — VOLTAGE REFERENCE DIODES AND VOLTAGE-REGULATOR DIODES

1. General terms 9
2. Terms related to ratings and characteristics 9
3. Letter symbols 9

SECTION THREE — CURRENT REGULATOR DIODES

1. General terms 10
2. Terms related to ratings and characteristics 11
3. Letter symbols 12

CHAPTER III: ESSENTIAL RATINGS AND CHARACTERISTICS

SECTION ONE — SIGNAL DIODES (INCLUDING SWITCHING DIODES)

1. General 14
2. Ratings (limiting values) 14
3. Characteristics 15
4. Application data (under consideration) 16

SECTION TWO — VOLTAGE-REFERENCE DIODES AND VOLTAGE-REGULATOR DIODES

1. General 16
2. Ratings (limiting values) 17
3. Characteristics 17

SECTION THREE — CURRENT-REGULATOR DIODES

Clause Page

1. Type 18
2. Semiconductor material 18
3. Outline 18
4. Limiting values (absolute maximum system) over the operating temperature range, unless otherwise specified 18
5. Electrical characteristics 19

CHAPTER IV: MEASURING METHODS

SECTION ONE — SIGNAL DIODES (INCLUDING SWITCHING DIODES)

1. Reverse current 20
2. Forward voltage 21
3. Total capacitance 22
4. Switching parameters 23
5. Detector efficiency 30
6. Noise 32

SECTION TWO — VOLTAGE-REFERENCE DIODES AND VOLTAGE-REGULATOR DIODES

1. Working voltage 33
2. Differential resistance 35
3. Temperature coefficient of working voltage 37
4. Reverse current 39
5. Forward voltage 39
6. Junction capacitance 39
7. Noise voltage 40

SECTION THREE — CURRENT-REGULATOR DIODES

1. Regulator current 41
2. Temperature coefficient of regulator current 41
3. Regulator current variation 42
4. Limiting voltage 43
5. Small-signal regulator conductance 44
6. Knee conductance 46

CHAPTER V: ACCEPTANCE AND RELIABILITY

SECTION ONE — ELECTRICAL ENDURANCE TESTS

1. General requirements 47
2. Specific requirements 47

Indian Standard

SEMICONDUCTOR DEVICES — DISCRETE DEVICES AND INTEGRATED CIRCUITS

PART 3 SIGNAL (INCLUDING SWITCHING) AND REGULATOR DIODES

CHAPTER I: GENERAL

1. Introductory note

As a rule, it will be necessary to use Publication 747-1 together with the present publication. In 747-1, the user will find all basic information on:

- terminology;
- letter symbols;
- essential ratings and characteristics;
- measuring methods;
- acceptance and reliability.

The sequence of the different chapters is in accordance with Publication 747-1, Chapter III, Sub-clause 2.1.

2. Purpose

The present publication gives standards for the following categories and sub-categories of devices:

- signal diodes (including switching diodes);
- voltage-reference diodes and voltage-regulator diodes;
- current-regulator diodes.

3. Letter symbols

Mostly, existing letter symbols are added to the terms in titles. When several distinctive forms exist, the most commonly used form is given.

CHAPTER II: TERMINOLOGY AND LETTER SYMBOLS

SECTION ONE — SIGNAL DIODES (INCLUDING SWITCHING DIODES)

1. General terms

The relevant terms and definitions given in Publication 747-1 apply. The term in Sub-clause 1.1 below is repeated from this publication, Chapter IV, Sub-clause 4.8.

1.1 *Signal diode*

A diode used for the purpose of extracting or processing information contained in an electronic signal which varies with time and may be either analogue or digital in nature.

2. Terms related to ratings and characteristics

The relevant terms and definitions given in Publication 747-1, Chapter IV, Clause 5, apply.

Additional terms and definitions are given below.

2.1 *Voltages*

2.1.1 *Continuous (direct) reverse voltage* (V_R)

The value of the constant voltage applied to a diode in the reverse direction.

2.1.2 *Mean reverse voltage* ($V_{R(AV)}$)

The value of the reverse voltage averaged over a specified time.

2.1.3 *Peak reverse voltage* (V_{RM})

The highest instantaneous value of the reverse voltage occurring across a diode, including all repetitive and non-repetitive transients.

2.1.4 *Detector voltage efficiency* (η_v)

The ratio of the d.c. load voltage to the peak sinusoidal input voltage under specified circuit conditions.

2.1.5 *Forward recovery voltage* (v_{FR})

The varying voltage occurring during the forward recovery time after instantaneous switching from zero or a specified reverse voltage to a specified forward current.

2.2 *Currents*

2.2.1 *Mean forward current* ($I_{F(AV)}$)

The value of the forward current averaged over a specified time.

2.2.2 *Peak forward current* (I_{FM})

The highest instantaneous value of the forward current, including all repetitive and non-repetitive transients.

2.3 *Power dissipation*

2.3.1 *Detector power efficiency* (η_p)

The ratio of the change in d.c. power in the load resistance produced by the a.c. signal, to the available power from a sinusoidal voltage generator when the diode is operated under specified conditions.

2.3.2 *Single-pulse energy* (E_p) *(applied to a detector diode)*

The energy of a pulse of short duration applied to a diode in the forward direction.

Note. — For maximum rating purposes, the pulse duration is normally specified to be less than 10 ms.

2.3.3 *Repetitive pulse energy* ($E_{p(rep)}$)

The energy contained in a single pulse that occurs in a repetitive series of pulses.

2.4 *Sundry characteristics*

2.4.1 *Recovered charge* (Q_r)

The total charge recovered from the diode after switching from a specified forward current condition to a specified reverse condition.

Note. — This charge includes components due to both carrier storage and depletion layer capacitance.

2.4.2 *Reverse recovery time* (t_{rr})

The time interval between the instant when the current passes through zero, when changing from the forward direction to the reverse direction, and the instant when the reverse current is reduced from its peak value I_{RM} to a specified low value (as shown in Figure 1), or when the extrapolated reverse current reaches zero (as shown in Figure 2, page 6).

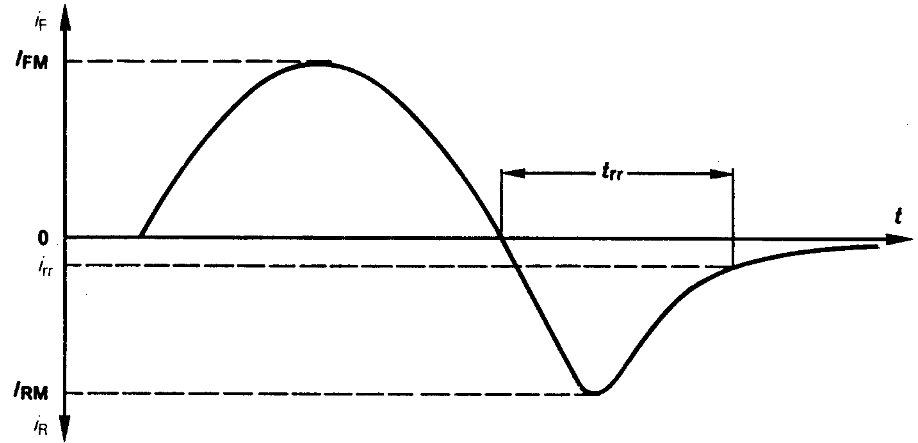


FIGURE 1

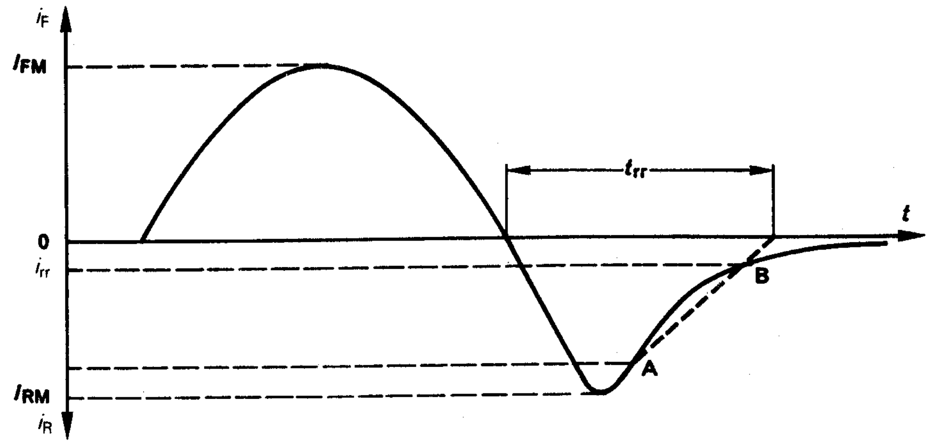


FIGURE 2

Note. — The extrapolation is carried out with respect to specified points A and B, as shown in generalized form in Figure 2.

2.4.3 *Forward recovery time* (t_{fr})

The time required for the current or voltage to recover to a specified value after instantaneous switching from zero or a specified reverse voltage to a specified forward bias condition.

2.4.4 *Differential resistance* (r)

The differential resistance measured between the terminals of the diode under specified conditions of measurement.

2.4.5 *Forward d.c. resistance*

The quotient of d.c. forward voltage across the diode and the corresponding d.c. forward current.

2.4.6 *Reverse d.c. resistance*

The quotient of the d.c. reverse voltage across the diode and the corresponding d.c. reverse current.

2.4.7 *Total capacitance* (C_{tot})

The differential capacitance at the diode terminals, measured under given bias conditions.

2.4.8 *Total current sensitivity* (β_I)

The quotient of:

1) the total rectified diode current with a specified load, and

2) the total delivered input signal power.

2.4.9 *Incremental current sensitivity* (β_i)

The quotient of:

1) the rectified diode current increment with a specified load, and

2) the change in delivered input signal power that induces this increment.

2.4.10 *Figure of merit (of a detector diode)* (M)

A parameter characterizing the sensitivity of a receiving device and defined by the formula:

$$M = \frac{\beta r_{op}}{\sqrt{N_r r_{op} + R_A}}$$

where:

β = either incremental current sensitivity (β_i)
or total current sensitivity (β_t)
as appropriate, in either case under short-circuit conditions

r_{op} = operating point resistance

N_r = noise ratio of the diode

R_A = equivalent noise resistance of the high-impedance amplifier that is used to amplify the output of the detector diode

3. Letter symbols

3.1 *General*

The general rules of Publication 747-1, Chapter V, apply.

3.2 *Additional subscripts*

In addition to the relevant recommended general subscripts (see Sub-clauses 2.2.1 and 3.3.1 of Publication 747-1, Chapter V), the following specific subscripts are recommended for:

3.2.1 *Currents, voltages and powers:*

A, a = anode
K, k = cathode
O = average output rectified

3.2.2 *Electrical parameters:*

δ, d = damping
r = recovery, recovered, rectified
S, s = storage, stored

3.3 *Additional list of letter symbols*

The letter symbols contained in the following list are recommended for use in the field of signal diodes; they have been compiled in accordance with the general rules.

Name and designation	Letter symbol	Remarks
3.3.1 Voltages		
Continuous (direct) forward voltage	V_F	
Instantaneous total forward voltage	v_F	
Average forward voltage	$V_{F(AV)}$	
Continuous (direct) reverse voltage	V_R	
Instantaneous total reverse voltage	v_R	
Peak reverse voltage	V_{RM}	
Surge reverse voltage	V_{RSM}	
Breakdown voltage	$V_{(BR)}$	
Forward recovery voltage	v_{FR}	
Peak value of forward recovery voltage	V_{FRM}	
3.3.2 Currents		
Continuous (direct) forward current	I_F	
Instantaneous forward current	i_F	
Peak forward current	I_{FM}	
Surge forward current	I_{FSM}	
Average output rectified current	I_O	
Continuous (direct) reverse current	I_R	
Instantaneous reverse current	i_R	
Peak reverse current	I_{RM}	
3.3.3 Powers		
Surge power	P_{SM}	
R.F. c.w. power dissipation	P_{CW}	For detector diodes
Pulse r.f. power dissipation	P_{RFP}	
3.3.4 Switching parameters		
Forward recovery time	t_{fr}	
Reverse recovery time	t_{rr}	
Reverse recovery current	i_{rr}	
Recovered charge	Q_r	
3.3.5 Sundry quantities		
Differential resistance	r	
Damping coefficient	δ or d	
Damping resistance	r_δ or r_d	
Efficiency	η	
Detector voltage efficiency	η_v	
Incremental current sensitivity	β_i	
Total current sensitivity	β_I	
Single-pulse energy	E_P, W_P	
Repetitive pulse energy	$E_{P(rep)}$	For detector diodes
Operating point differential resistance	r_{op}	
Figure of merit	M	

SECTION TWO — VOLTAGE-REFERENCE DIODES AND VOLTAGE-REGULATOR DIODES

1. General terms

The relevant terms and definitions given in Publication 747-1, apply. The terms in Sub-clauses 1.1 and 1.2 below are repeated from this publication, Chapter IV, Sub-clauses 4.10 and 4.11.

Further specific terms are given below.

1.1 *Voltage-reference diode*

A diode which develops across its terminals a reference voltage of specified accuracy, when biased to operate within a specified current range.

1.2 *Voltage-regulator diode*

A diode which develops across its terminals an essentially constant voltage throughout a specified current range.

1.3 *Forward direction*

Under consideration.

1.4 *Reverse direction*

Under consideration.

2. Terms related to ratings and characteristics

The relevant terms and definitions given in Publication 747-1, Chapter IV, Clause 5, apply.

3. Letter symbols

3.1 *General*

The general rules of Publication 747-1, Chapter V, apply.

3.2 *Additional subscripts*

In addition to the relevant recommended general subscripts (see Sub-clauses 2.2.1 and 3.3.1 of Publication 747-1, Chapter V), the following specific subscripts are recommended for:

3.2.1 *Currents, voltages and powers*

Z, z = working

3.2.2 *Electrical parameters*

Z, z = working

3.3 *Additional list of letter symbols*

The letter symbols contained in the following list are recommended for use in the field of voltage-reference and voltage-regulator diodes; they have been compiled in accordance with the general rules.

Name and designation	Letter symbol	Remarks
3.3.1 Voltages		
Working voltage	V_Z	
Continuous (direct) reverse voltage below the working voltage range	V_R	
Noise voltage within the working voltage range	V_{nZ}	The symbol V_n is also acceptable if no misunderstanding is possible
3.3.2 Currents		
Continuous (direct) reverse current within the working voltage range	I_Z	
Continuous (direct) reverse current at a voltage below the working voltage range	I_R	
3.3.3 Sundry quantities		
Differential resistance within the working voltage range	r_z	
Temperature coefficient of working voltage	α_{VZ}	Reserve symbol: S_Z
Working voltage long-term instability	δ_{VZ}	For voltage-reference diodes

SECTION THREE — CURRENT-REGULATOR DIODES

1. General terms

The relevant terms and definitions given in Publication 747-1, apply. The term in Sub-clause 1.1 below is repeated from this publication, Chapter IV, Sub-clause 4.12.

Further specific terms are given below.

1.1 *Current-regulator diode*

A diode that limits current to an essentially constant value over a specified voltage range.

1.2 *Anode*

The electrode from which current flows within the diode when it is biased to operate as a current regulator.

1.3 *Cathode*

The electrode to which current flows within the diode when it is biased to operate as a current regulator.

2. **Terms related to ratings and characteristics**

The relevant terms and definitions given in Publication 747-1, Chapter IV, Clause 5, apply.

Additional terms and definitions are given below.

2.1 *Voltages*

2.1.1 *Regulating range*

The range of voltages within which the current is maintained between specified narrow limits.

2.1.2 *Regulator voltage (working voltage)* (V_S)

A voltage within the regulating range of a current-regulator diode.

2.1.3 *Limiting voltage* (V_L)

The voltage at point I_L' on the current-voltage characteristic.

2.1.4 *Knee voltage* (V_K)

A voltage near the lower knee of the current-voltage characteristic.

2.2 *Currents*

2.2.1 *Regulator current (working current)* (I_S)

A current within the regulating range of a current-regulator diode.

2.2.2 *Limiting current* (I_L)

A specified current below the regulating range.

2.3 *Power dissipation*

2.4 *Sundry characteristics*

2.4.1 *Small-signal regulator conductance* (g_s)

The small-signal conductance within the regulating range of a current-regulator diode.

2.4.2 *Knee conductance* (g_k)

The small-signal regulator conductance at the knee voltage.

2.4.3 *Temperature coefficient of regulator current (working current)* (α_{IS})

The quotient of the change in regulator current (working current) between two specified values of temperature and that change of temperature.

Note. — The change in regulator current (working current) is usually expressed as a percentage of regulator current (working current).

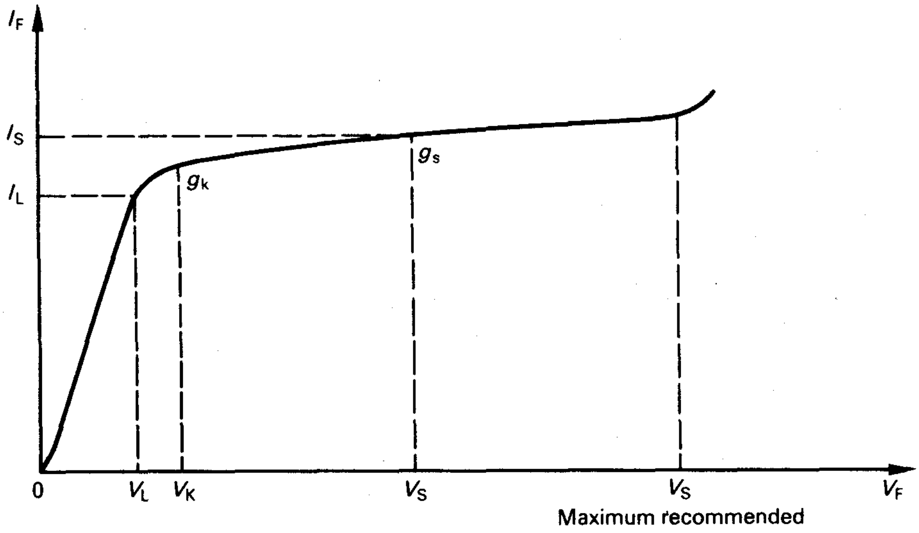


FIG. 3. — Current-regulator diode characteristic with symbol identification.

3. Letter symbols

3.1 *General*

The general rules of Publication 747-1, Chapter V, apply.

3.2 *Additional subscripts*

In addition to the relevant recommended general subscripts (see Sub-clauses 2.2.1 and 3.3.1 of Publication 747-1, Chapter V), the following specific subscripts are recommended for:

3.2.1 *Currents, voltages and powers*

S, s = regulator (working)
L = limiting
K = knee

3.2.2 *Electrical parameters*

S, s = regulator (working)
k = knee

3.3 *Additional list of letter symbols*

The symbols contained in the following list are recommended for use in the field of current-regulator diodes; they have been compiled in accordance with the general rules.

Name and designation	Letter symbol	Remarks
3.3.1 Voltages		
Regulator voltage (working voltage)	V_S	
Limiting voltage	V_L	
Knee voltage	V_K	
3.3.2 Currents		
Regulator current (working current)	I_S	
Limiting current	I_L	
3.3.3 Sundry quantities		
Small-signal regulator conductance	g_s	
Knee conductance	g_k	
Temperature coefficient of regulator current (working current)	α_{IS}	
Regulator current variation	ΔI_S	

CHAPTER III: ESSENTIAL RATINGS AND CHARACTERISTICS

SECTION ONE — SIGNAL DIODES (INCLUDING SWITCHING DIODES)

1. General

1.1 *Range of application*

The provisions of this section are not intended to cover diodes designed to operate at frequencies above several hundred MHz.

1.2 *Rating methods*

Signal diodes should be specified as ambient-rated or case-rated devices or, where appropriate, as both.

1.3 *Recommended temperatures*

Many of the ratings and characteristics are required to be quoted at a temperature of 25 °C, and at another specified temperature. Unless otherwise stated, the one other temperature should be chosen by the manufacturer from the list in Publication 747-1, Chapter VI, Clause 5.

2. Ratings (limiting values)

The following ratings should be stated:

2.1 *Temperatures*

2.1.1 *Minimum and maximum storage temperatures* (T_{stg})

2.1.2 *Minimum and maximum operating ambient or case temperatures* (T_{amb} or T_{case})

2.2 *Voltages and currents*

The voltage and current ratings given must cover the operation of the device over the rated range of operating temperatures. Where such ratings (e.g. forward current, reverse voltage, etc.) are temperature-dependent, this dependence should be indicated.

2.2.1 *Maximum continuous (direct) reverse voltage* (V_R)

2.2.2 *Maximum peak reverse voltage at specified pulse conditions (for switching diodes)* (V_{RM})

2.2.3 *Maximum continuous (direct) forward current* (I_F)

2.2.4 *Excluding switching diodes, maximum peak forward current under specified conditions* (I_{FM})

2.2.5 *For switching diodes, peak forward current for a specified pulse duration and at a specified duty cycle* (I_{FM})

2.3 *Power dissipation (where appropriate)*

Maximum power dissipation as a function of temperature (P), or

Maximum thermal resistance junction-to-case ($R_{th(j-c)}$) or junction-to-ambient ($R_{th(j-amb)}$), maximum virtual junction temperature ($T_{(vj)}$) and maximum value of power dissipation (P).

Any special requirements for ventilation and/or mounting shall be specified.

3. Characteristics

The following characteristics shall be stated. The values shall be stated at one of the voltages and/or currents taken from the list in Publication 747-1, Chapter VI, Clause 6.

3.1 *Reverse current* (I_R)

Maximum value at the maximum continuous (direct) reverse voltage and at a low value of reverse voltage at 25 °C and one higher temperature taken from the list in Publication 747-1, Chapter VI, Clause 5.

3.2 *Forward voltage* (V_F)

Maximum value at the rated maximum continuous (direct) forward current at 25 °C.

Minimum value at low value of continuous (direct) forward current at 25 °C.

3.3 *Total capacitance* (C_{tot})

Maximum value at specified low value of reverse voltage at 25 °C; the frequency shall be below that where complicating secondary effects are significant.

3.4 *Switching parameters*

For diodes specified for use in switching applications, the following characteristics should be stated at 25 °C:

3.4.1 *Either: a) Recovered charge* (Q_r)

Maximum value under specified conditions of forward current and specified reverse circuit conditions.

Or: b) Reverse recovery time (t_{rr}).

When the maximum value of recovered charge cannot be stated (Sub-clause 3.4.1*a)*), a maximum value for reverse recovery time should be stated when switching from a specified forward current by the application of specified reverse voltage or current and for specified circuit conditions.

3.4.2 *Peak forward recovery voltage* (v_{FRM}) *(where appropriate)*

Maximum value when switching from a specified reverse voltage to a specified forward current.

3.4.3 *Forward recovery time* (t_{fr}) *(where appropriate)*

Maximum value when switching from a specified reverse bias to a specified forward current.

3.5 *Detector efficiency*

For diodes specified for use in detector circuits, the following characteristics shall be stated:

Either: a) Detector voltage efficiency (η_v)

Minimum value at 25 °C and at specified bias conditions. The circuit conditions and the frequency of measurement shall also be specified.

This characteristic is usually stated for high-level r.f. detectors.

Or: b) Detector power efficiency (η_p)

Minimum value under specified bias conditions at 25 °C and at one higher temperature taken from the list in Publication 747-1, Chapter VI, Clause 5. The circuit conditions and the frequency of measurement shall also be specified.

This characteristic is usually stated for low-level r.f. detectors.

3.6 *Noise* (V_n, I_n) *(where appropriate)*

Maximum value of noise voltage or current, depending respectively on whether the diode is forward or reverse biased.

4. Application data

Under consideration.

SECTION TWO — VOLTAGE-REFERENCE DIODES AND VOLTAGE-REGULATOR DIODES

1. General

1.1 *Rating methods*

Voltage-reference and voltage-regulator diodes should be specified either as ambient-rated or case-rated devices or, where appropriate, as both.

1.2 *Recommended temperatures*

Many of the ratings and characteristics are required to be quoted at a temperature of 25 °C, and at another specified temperature. Unless otherwise stated, the one other temperature should be chosen by the manufacturer from the list in Publication 747-1, Chapter VI, Clause 5.

2. Ratings (limiting values)

The following ratings should be stated:

2.1 *Temperatures*

2.1.1 *Minimum and maximum storage temperatures* (T_{stg})

2.1.2 *Minimum and maximum operating ambient or case temperatures* (T_{amb} or T_{case})

2.2 *Currents*

These ratings must cover the operation of the device over the rated range of operating temperatures. Where such ratings are temperature dependent, this dependence should be indicated.

2.2.1 *Maximum continuous (direct) reverse current* (I_Z) *(for diodes intended for operation in the breakdown region)*

2.2.2 *Maximum continuous (direct) forward current* (I_F) *(for diodes intended for operation in the forward conductivity region)*

3. Characteristics

3.1 *General*

Characteristics shall be stated at 25 °C and, where appropriate, at one other specified temperature, taken from the list in Publication 747-1, Chapter VI, Clause 5.

3.2 *Working voltage* (V_Z)

Nominal, minimum and maximum values at a specified current in the scale 1, 2, 5.

For voltage-reference diodes operating in the reverse breakdown mode, the preferred nominal values of voltages and their respective limits are given in Publication 747-1, Chapter VI, Sub-clauses 6.3 and 6.4.

3.3 *Differential resistance within the working voltage range* (r_z)

3.3.1 *Maximum value at the current specified in Sub-clause 3.2*

3.3.2 *Maximum value at a recommended minimum operating current*

3.4 *Temperature coefficient of working voltage* (α_{VZ})

Minimum and maximum values (% per degree Celsius) at the current specified in Sub-clause 3.2. If this coefficient varies significantly with the temperature, the variation shall be stated, and the temperatures at which the measurements are made shall be specified.

3.5 *Junction capacitance (where appropriate)*

Maximum value at a specified reverse voltage below the breakdown voltage.

3.6 *Reverse current* (I_R)

Maximum value at a specified reverse voltage below the breakdown voltage.

3.7 *Forward voltage* (V_F) *(for voltage-regulator diodes only) (where appropriate)*

Typical or maximum value at the maximum continuous (direct) forward current for diodes intended for operation in the breakdown region.

3.8 *Noise voltage within the working voltage range* (V_{nz}) *(where appropriate)*

Maximum value under specified conditions of frequency, bandwidth and operating current. The variation of this parameter with temperature shall be indicated, when such a variation is significant.

SECTION THREE — CURRENT-REGULATOR DIODES

1. Type

Ambient-rated or case-rated current-regulator diode.

2. Semiconductor material

Silicon, etc.

3. Outline

3.1 *IEC reference, either: 1) device outline drawing (Code A);*
or: 2) base (Code B) followed by case (Code C).

(National references may be added.)

3.2 *Case material: glass/metal/plastic/other*

3.3 *Terminal identification and indication of any connection between a terminal and the case*

4. Limiting values (absolute maximum system) over the operating temperature range, unless otherwise specified

4.1 *Minimum and maximum storage temperatures* (T_{stg})

4.2 *Minimum and maximum operating ambient or case temperatures* (T_{amb} or T_{case})

4.3 *Maximum total power dissipation at an ambient or case temperature of 25 °C* (P_{tot}) *and a derating curve or derating factor*

4.4 *Where appropriate, either maximum reverse (negative anode-cathode) voltage* (V_R) *or maximum reverse current* (I_R)

4.5 *Where appropriate, maximum forward voltage* (V_F)

5. Electrical characteristics

Reference	Characteristic	Conditions at T_{amb} or $T_{case}=25$ °C, unless otherwise specified	Symbol	Requirements
5.1	Regulator current	V_S specified (V_{S1})	I_{S1}	min. max.
5.2	Regulator current	V_S specified at the maximum recommended operating voltage (V_{S2})	I_{S2}	max.
5.3	Where appropriate, temperature coefficient of regulator current	V_S specified as in Sub-clause 5.1, range of T_{amb} or T_{case}	α_{IS}	min. max. * *
Either: 5.4	Regulator current variation for a specified change of V_S	Two specified values of V_S on either side of V_{S1}	ΔI_S	max.
Or: 5.5	Small-signal regulator conductance	V_{S1}, $f=1$ kHz	g_s	max.
5.6	Limiting voltage	I_L specified, preferably 0.8 I_{S1} min.	V_L	max.
5.7	Where appropriate, knee conductance	V_K specified, $f=1$ kHz	g_k	max.

* "Maximum" is the most positive (least negative) limit; "minimum" is the least positive (most negative) limit. The signs (+/−) associated with each limit shall be given.

CHAPTER IV: MEASURING METHODS

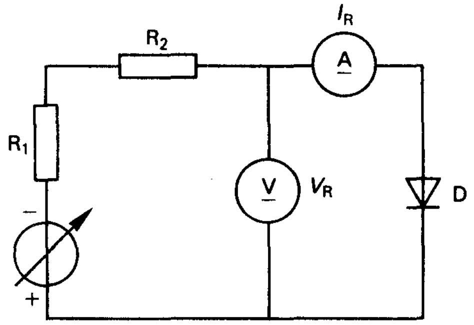
SECTION ONE — SIGNAL DIODES (INCLUDING SWITCHING DIODES)

1. Reverse current I_R

a) Purpose

To measure the reverse current of a diode under specified reverse voltage.

b) Circuit diagram



D = diode being measured

FIG. 4. — Circuit diagram for the measurement of I_R.

c) Circuit description and requirements

R_1 is a calibrated resistor (pulse measurement only).

R_2 is a protective resistor.

If a pulse measurement is required, the variable voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument and the ammeter is replaced by a peak-reading voltmeter across the calibrated resistor R_1.

d) Measurement procedure

The temperature is set to the specified value.

The variable voltage generator is adjusted to obtain the specified value of reverse voltage V_R across the diode.

The reverse current I_R is read from the ammeter A.

e) Specified conditions

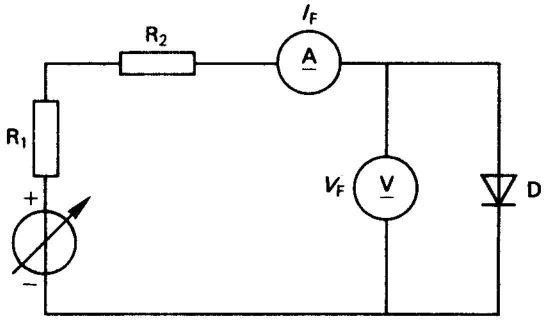
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- reverse voltage (V_R);
- pulse width and duty cycle, where applicable.

2. **Forward voltage V_F**

a) Purpose

To measure the forward voltage across a signal or switching diode under specified conditions.

b) Circuit diagram



D = diode being measured

FIG. 5. — Circuit diagram for the measurement of V_F.

c) Circuit description and requirements

R_1 is a calibrated resistor (pulse measurement only).

R_2 is a high-value resistor.

If a pulse measurement is required, the variable voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument and the ammeter is replaced by a peak-reading voltmeter across the calibrated resistor R_1.

d) Measurement procedure

The temperature is set to the specified value.

The variable voltage generator is adjusted to obtain the specified value of forward current I_F.

The forward voltage V_F is read from the voltmeter V.

e) Specified conditions

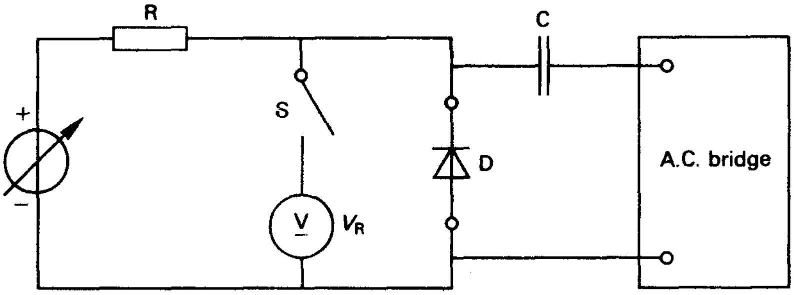
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- forward current (I_F);
- pulse width and duty cycle, where applicable.

3. **Total capacitance** C_{tot}

a) Purpose

To measure the total capacitance of a diode under specified conditions.

b) Circuit diagram



D = diode being measured

FIG. 6. — Circuit diagram for the measurement for C_{tot}.

c) Circuit description and requirements

The conductance of resistor R should be low compared with the admittance of the diode being measured.

The capacitor C should be able to withstand the reverse bias voltage of the diode and should present a short-circuit at the frequency of measurement.

d) Precautions to be observed

If the measured capacitance is very small, the mounting conditions will affect the accuracy of the results and they should be specified.

e) Measurement procedure

The temperature is set to the specified value.

The voltage across the diode is adjusted to the specified value V_R. Then the voltmeter V is taken out of the circuit and the capacitance of the diode being measured is determined, using the a.c. bridge, by subtracting the value without the diode in its mounting from the value with the diode in its mounting.

f) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- reverse voltage (V_R);
- measurement frequency, if different from 1 MHz;
- mounting conditions of the diode, if necessary.

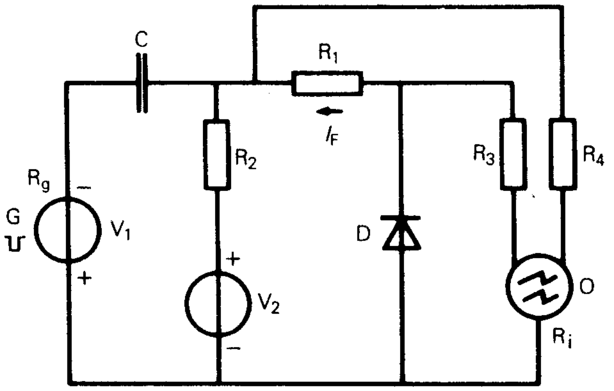
4. Switching parameters

4.1 *Forward recovery time t_{fr} and peak forward recovery voltage V_{FRM}*

a) Purpose

To measure the forward recovery time and the peak forward recovery voltage of a switching diode.

b) Circuit diagram



D = diode being measured

FIG. 7. — Circuit diagram for the measurement of t_{fr} and V_{FRM}.

c) Circuit description and requirements

Pulse generator G supplies the specified forward current pulses I_{FM}; voltage generator V_2 and resistor R_2 supply the specified reverse voltage bias V_R if different from zero.

The value of R_1 should be chosen so that $I_{FM} \times R_1$ is large compared with the forward voltage drop across the diode; the value of C should be chosen so that the time constant $C(R_1 + R_g)$ is large compared with the pulse width, where R_g is the output impedance of generator G. Capacitor C is not required if no reverse bias is applied.

The value of R_2 should be large compared with R_1 and R_g but small enough so that the voltage drop across it caused by the reverse current of the diode is negligible.

R_3 and R_4 are low-inductance resistors and should have values that are large together with the input impedance R_i of the oscilloscope in comparison with the forward impedance of the diode.

O is a double-trace oscilloscope with internal resistance R_i.

d) Measurement procedure

The temperature is set to the specified value.

The generator output voltage V_1 is increased from zero until the specified forward current value:

$$I_{FM} \approx \frac{V_1}{R_1 + R_g}$$

is reached.

The forward recovery time and the peak forward recovery voltage are measured on the oscilloscope.

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});

- reverse voltage (V_R), if different from zero;
- peak forward current (I_{FM});
- forward recovery voltage V_{FR}, defining the end of the reverse recovery time, if different from 110% V_F;
- pulse characteristics: duration, rise time and repetition frequency;

- values of R_l and R_g.

4.2 *Recovered charge Q_r, reverse recovery time t_{rr}*

4.2.1 *Introduction*

When a diode is switched suddenly from operation in the forward direction to the reverse direction, there is an initial transient of reverse current which then decays to the final value of the reverse current of the diode as shown in Figure 10, page 28.

This phenomenon may limit the speed of switching circuits.

There are two methods in common use of specifying the reverse recovery characteristic of a diode.

The first method is to operate the diode in a circuit in which the forward current, reverse voltage, circuit impedances and switching pulse shape are fully specified. The time between the commencement of the fall of forward current and the instant when the reverse current falls to a specified value, after passing through a peak, is measured and is quoted as the reverse recovery time (see Figure 10). The disadvantage of this method is that the quoted value of reverse recovery time applies only in the circuit conditions specified, and is not directly applicable to a different set of circuit conditions.

The second method uses the fact that the basic cause of the reverse recovery characteristic is the charge stored by the diode. This charge comprises two parts: the first due to minority carriers, and the second due to the charge of the diode capacitance. The total charge extracted from the diode, when switching from a specified forward current to a specified reverse voltage in a specified circuit, is termed the recovered charge.

Provided the proportion of the charge due to the diode capacitance is negligible and the circuit impedance is low, the recovered charge will be approximately proportional to the diode forward current at the instant of switching and substantially independent of the applied reverse voltage.

Under these conditions, the recovered charge for unit forward current is a characteristic of the diode, and is substantially independent of the circuit conditions. It is preferable, therefore, to specify diodes in terms of recovered charge whenever possible.

The following example is given to demonstrate the use of the recovered charge concept:

Consider a diode which is specified as having a recovered charge of 500 pC when switching off a forward current of 10 mA, under the conditions specified in this measuring method.

The recovery time of this diode when switching off 2 mA with a reverse voltage of 10 V in a circuit of loop impedance of 10000 ohms can be calculated as follows:

The recovered charge is: $500 \text{ pC} \times \frac{2 \text{ mA}}{10 \text{ mA}} = 100 \text{ pC}$.

Until the stored charge in the diode is exhausted, the reverse current after switching will be limited by the external circuit, and will be:

$$\frac{10 \text{ V}}{10\,000 \text{ ohms}} = 1 \text{ mA}.$$

The time taken to remove the charge is $\frac{100 \text{ pC}}{1 \text{ mA}} = 100 \text{ ns}$.

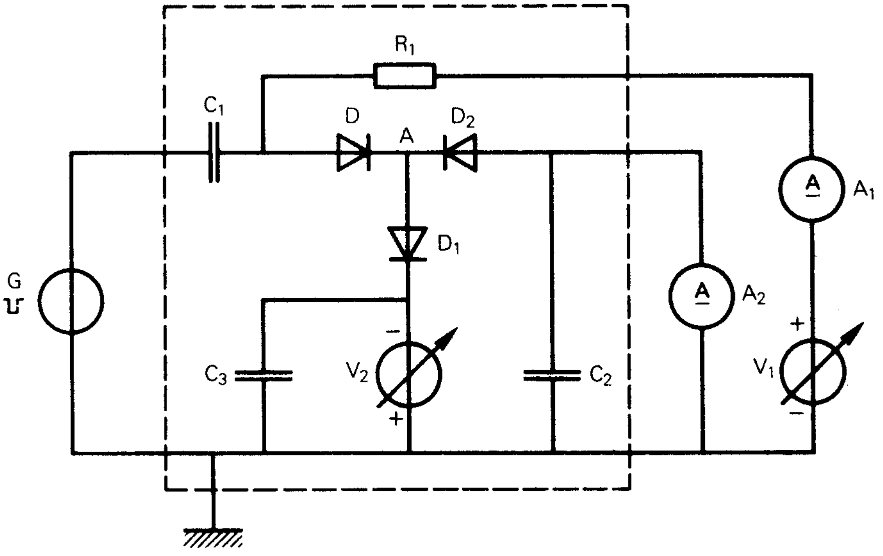
This is the derived value of the reverse recovery time of the diode under these conditions.

4.2.2 *Recovered charge Q_r*

a) Purpose

To measure the charge recovered from a diode when it is rapidly switched from a forward biased condition to a reverse biased condition.

b) Circuit diagram



D = diode being measured

FIG. 8. — Circuit diagram for the measurement of Q_r.

c) Circuit description and requirements

C_1 should be small enough to be fully discharged during the interval between pulses:

$$R_gC_1 \ll \frac{1}{f}$$

where R_g is the internal resistance of the pulse generator G.

R_1 should be large enough to ensure a constant current through the diode being measured.

Diodes D_1 and D_2 should have negligible reverse current under the measuring circuit conditions. Diode D_1 should have a much smaller recovered charge than the device being measured. C_2 is chosen to average out the current through ammeter A_2:

$$R_aC_2 \gg t_p,$$

where R_a is the internal resistance of the ammeter A_2.

d) Measurement procedure

The temperature is set to the specified value.

With the pulse generator out of circuit, V_1 is adjusted to obtain the specified forward current I_F read on A_1, and V_2 is adjusted to give a voltage between point A and ground, just below the forward threshold voltage of D_2, e.g. 0.6 V for silicon diodes.

The pulse generator is adjusted to the specified conditions of amplitude V_g, pulse width t_p, rise time t_r and frequency f.

With the voltage generator V_1 out of circuit and the pulse generator G switched on, a current I_1 is read on ammeter A_2.

With both the voltage generator V_1 and the pulse generator G switched on, a current I_2 is read on ammeter A_2.

The recovered charge is calculated using the following expression:

$$Q_r = \frac{I_2 - I_1}{f}$$

e) Precautions to be observed

The portion of the circuit within the dotted lines should be constructed in accordance with good practice for fast-switching circuits. Particular attention should be paid to minimize the circuit inductances including the connections to the diode being measured.

f) Specified conditions

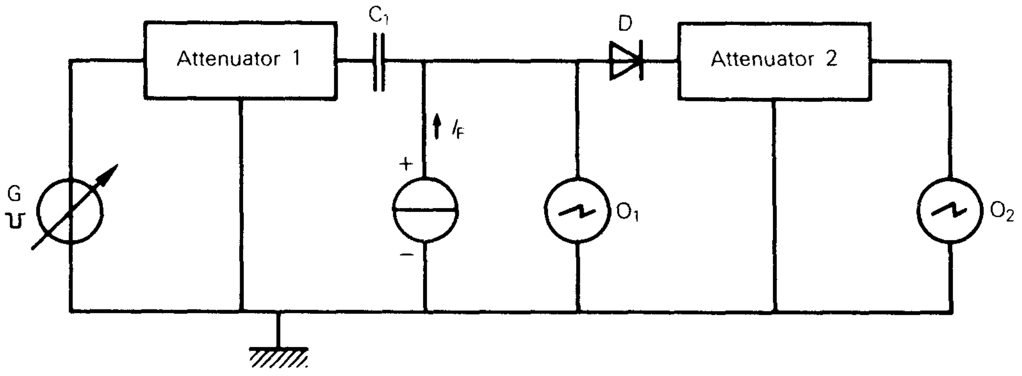
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- forward current (I_F);
- pulse amplitude (V_g), pulse width (t_p), rise time (t_r) and repetition frequency (f).

4.2.3 *Reverse recovery time t_{rr} (for a specified V_R)*

a) Purpose

To measure the reverse recovery time of a diode under specified switching conditions.

b) Circuit diagram



D = diode being measured

FIG. 9. — Circuit diagram for the measurement of t_{rr}.

c) Circuit description and requirements

The output impedance R_G of the generator G and the input impedance R_S of the oscilloscope O_2 are equal to 50 ohms unless otherwise specified. The rise times of the generator and of the oscilloscope should be small compared to t_{rr}.

The pulse width t_p should be larger than 3 times the specified value of t_{rr}max.

Attenuators 1 and 2 are optional and may be used to improve the matching of the pulse generator and of the oscilloscope and should have an attenuation higher than or equal to 6 dB.

The time constant R_LC_L should be lower than 0.1 t_{rr}max., unless otherwise specified, with:

$R_L = R_G + R_S$ = real part of the total impedance, as seen by the diode, that is 100 ohms unless otherwise specified

C_L = total capacitance of the circuit including the diode.

C_1 should be high compared to $t_{rr}\text{max}/R_L$.

The impedance Z_i of the current generator should be high compared to R_L.

The input impedance of oscilloscope O_1 that measures the voltage V_R applied to the diode should be high compared to R_L.

A dual-trace oscilloscope may be used instead of oscilloscopes O_1 and O_2.

d) Measurement procedure

The temperature is set to the specified value.

The current generator delivers the specified forward current I_F to the diode.

Pulses delivered by generator G are applied to the diode; the magnitude of the pulses is increased until, on oscilloscope O_1, the specified value V_R applied to the diode in the off-state is reached.

On the oscilloscope O_2, the reverse recovery time t_{rr} is measured from the instant when the current is equal to zero to the instant when the reverse current is reduced to the specified recovery current i_{rr} (see Figure 10).

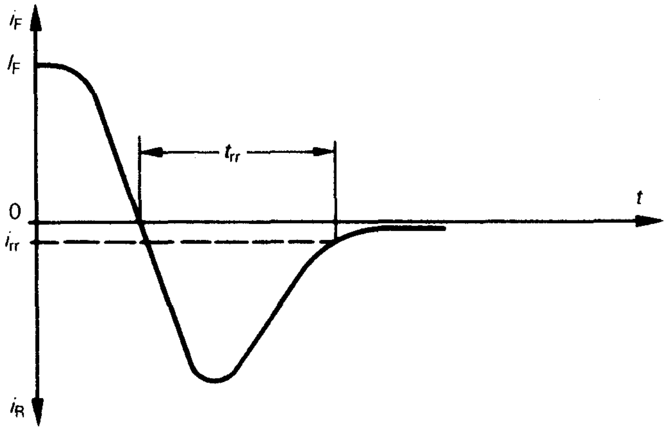


FIG. 10. — Diode current waveform in the measurement of t_{rr}.

e) Specified conditions

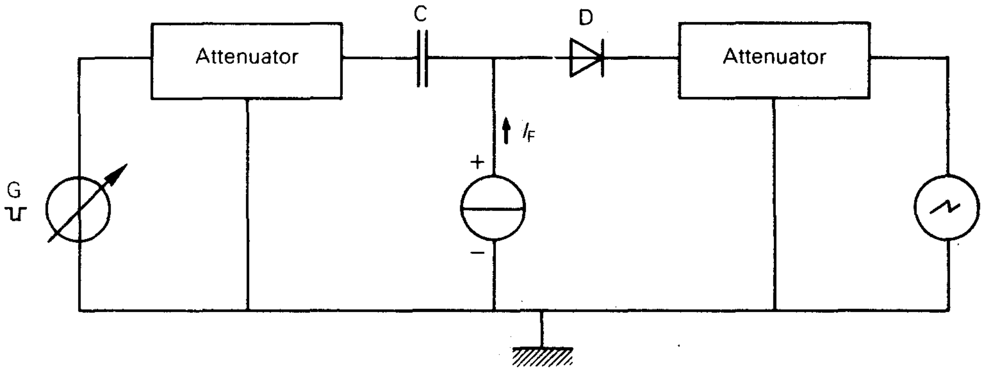
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- forward current (I_F);
- recovery current (i_{rr}), 0.1 I_F typical unless otherwise stated;
- reverse voltage (V_R) applied to the diode;
- total load resistance as seen by the diode, R_L (or R_G and R_S), if different from 100 ohms.

4.2.4 *Reverse recovery time t_{rr} (for a specified I_{RM})*

a) Purpose

To measure the reverse recovery time of a fast diode, e.g. with reverse recovery time less than 100 ns.

b) Circuit diagram



D = diode being measured

FIG. 11. — Circuit diagram for the measurement of t_{rr}.

c) Circuit description and requirements

The output impedance of the generator G and the input impedance of the oscilloscope are equal to 50 ohms unless otherwise specified. The rise times of the generator and of the oscilloscope should be small compared with t_{rr}.

The pulse width should be larger than 3 t_{rr}max.

Attenuators should have a characteristic impedance of 50 ohms unless otherwise specified, should have an attenuation higher than or equal to 6 dB and should be able to carry d.c.

The time constant $R_L C_L$ should be lower than 0.1 t_{rr}max., unless otherwise specified, with:

R_L = real part of the total impedance, as seen by the diode.

C_L = total capacitance of the circuit including the diode.

C should be high compared with t_{rr}max./R_L.

The impedance Z_i of the current generator should be greater than R_L.

d) Precautions to be observed

No special precaution.

e) Measurement procedure

The temperature is set to the specified value.

The current generator delivers the specified forward current I_F to the diode.

Pulses, delivered by generator G, are applied to the diode; the magnitude of the pulses is increased until the specified peak reverse current I_{RM} is reached.

The reverse recovery time t_{rr} is the time interval between the instant at which the current passes through zero and the instant when the current is reduced from I_{RM} to the specified recovery current i_{rr} (see Figure 12).

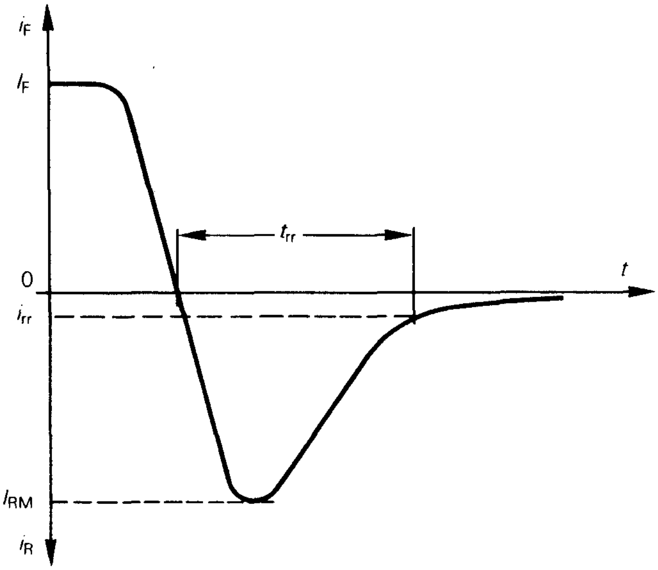


FIG. 12. — Diode current waveform in the measurement of t_{rr}.

f) Specified conditions

- ambient or reference-point temperature (T_{amb}, T_{ref});
- forward current (I_F);
- peak reverse current (I_{RM});
- reverse recovery current (i_{rr}).

Example of specified conditions: I_F = 10 mA
I_{RM} = 10 mA
i_{rr} = 1 mA

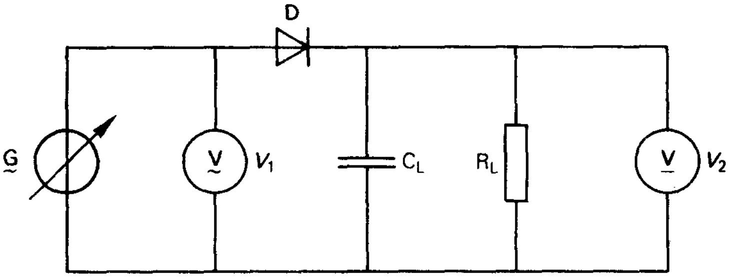
5. Detector efficiency

5.1 *Detector voltage efficiency* η_v

a) Purpose

To measure the detector voltage efficiency of a signal diode under specified conditions.

b) Circuit diagram



D = diode being measured

FIG. 13. — Circuit diagram for the measurement of η_v.

c) Circuit description and requirements

G is a low-impedance generator.

V is a r.m.s. reading voltmeter.

The value of R_L should be high compared with the value of the output impedance of the generator and the value of the forward impedance of the diode.

d) Measurement procedure

The temperature is set to the specified value.

The generator is adjusted to give the specified r.m.s. value of V_1.

V_2 is read from the voltmeter and the detector voltage efficiency is calculated using the expression:

$$\eta_v = \frac{V_2}{V_1 \sqrt{2}} \; (\times 100\%)$$

e) Specified conditions

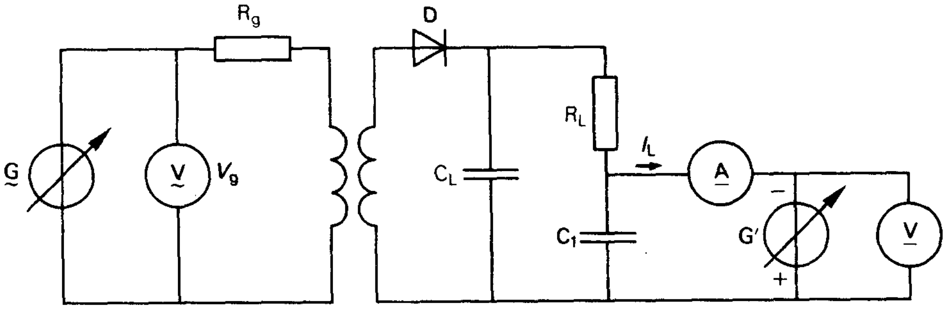
- ambient, case or reference-point temperature ($T_{\rm amb}$, $T_{\rm case}$, $T_{\rm ref}$);
- measurement frequency (usually 100 MHz);
- circuit parameters (R_L and C_L);
- voltage V_i (r.m.s. value).

5.2 *Detector power efficiency* η_p

a) Purpose

To measure the detector power efficiency of a signal diode under specified conditions.

b) Circuit diagram



D = diode being measured

FIG. 14. — Circuit diagram for the measurement of η_p.

c) Circuit description and requirements

G is a low-impedance generator.

V is an electronic voltmeter.

The transformer should have a low loss, and the equivalent value of the loss resistance should be included in R_g.

The turns ratio of the transformer should be such as to ensure impedance matching between R_g and R_L.

The value of R_L should be high compared with the value of the forward impedance of the diode. The time constant C_LR_L should be large compared to the reciprocal of the measurement frequency.

Capacitor C_1 should provide a short-circuit at the measurement frequency.

d) Measurement procedure

The temperature is set to the specified value.

The a.c. voltage generator is set to zero, and the d.c. voltage generator is set to give the specified forward bias conditions. The current I_{L1} is read from the d.c. ammeter A.

The a.c. voltage generator is set to the specified r.m.s. voltage V_g and the new value I_{L2} is read from the ammeter.

The detector power efficiency is calculated using the expression:

$$\eta_p = \frac{4(I_{L2} - I_{L1})^2 \cdot R_L \cdot R_g}{V_g^2} \ (\times 100\%)$$

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- measurement frequency (f) and voltage (V_g);
- d.c. bias conditions;
- circuit parameters (R_L and C_L);
- generator impedance (R_g).

6. Noise V_n, I_n

The noise of a diode can be represented either by a noise voltage source V_n in series with the diode or, preferably, by a noise current source I_n in parallel with the diode as shown in Figure 15, page 33 .

Figure 16, page 33, shows an example of a basic circuit for measuring I_n.

The recommended values for the limits of the pass-band of the filter are: 900 Hz and 1 100 Hz.

The voltage drop produced by the noise current of the diode is measured in the load resistor after amplification by means of a pass-band amplifier having a determined bandwidth and gain. At the output, the noise voltage is observed with a square-law voltmeter. The noise current in the pass-band is given as follows:

$$\sqrt{\overline{I_n^2}} = \frac{\sqrt{\overline{V_n^2}}}{A_v R}$$

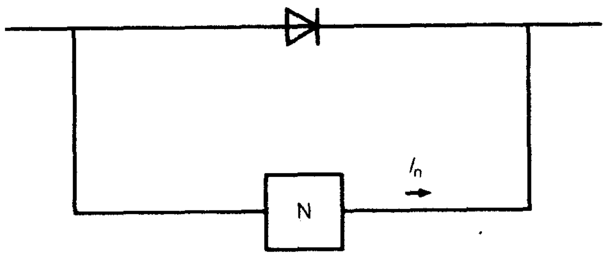
where:

A_v = voltage amplification of the amplifier plus filter.

The noise current may be brought back by calculation to 1 Hz of bandwidth.

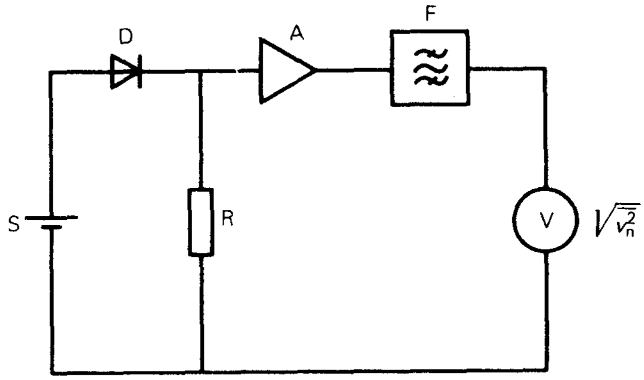
The diode may be biased in either direction to obtain noise values in either forward or reverse directions.

The noise introduced by the amplifier, the load resistance and the d.c. source shall be negligible. If this is not the case, it is necessary to make a correction obtained by measuring the noise with the diode replaced by an appropriate resistor.



N = noise current source

FIG. 15. — Circuit for the representation of the noise in a diode.



A = low-noise amplifier
D = diode being measured
F = pass-band filter
S = d.c. source
V = square-law voltmeter

FIG. 16. — Circuit for the measurement of noise current.

SECTION TWO — VOLTAGE-REFERENCE DIODES AND VOLTAGE-REGULATOR DIODES

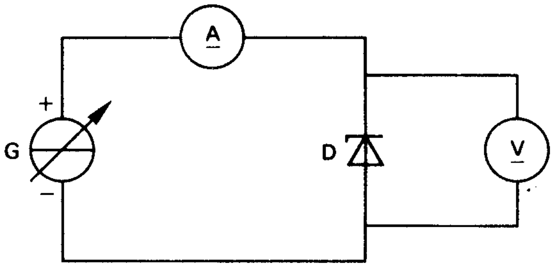
1. Working voltage V_Z

1.1 *Working voltage (d.c. method)*

a) Purpose

To measure the working voltage corresponding to a specified working current.

b) Circuit diagram



D = diode being measured

FIG. 17. — Circuit diagram for the measurement of V_Z (d.c. method).

c) Circuit description and requirements

The voltmeter V should have a high resistance compared with the resistance of the diode at the working voltage.

d) Measurement procedure

The temperature is set to the specified value.

The working d.c. current is set to the specified value I_Z as read on ammeter A, and the working voltage V_Z across the diode is measured.

e) Specified conditions

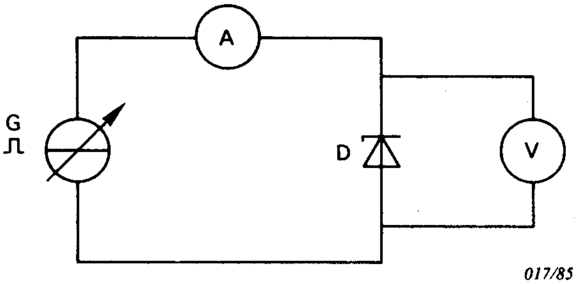
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- working current (I_Z);
- mounting conditions including length of leads, if necessary.

2 *Working voltage (pulse method)*

a) Purpose

To measure the working voltage corresponding to a specified working current under pulse conditions.

b) Circuit diagram



D = diode being measured

FIG. 18. — Circuit diagram for the measurement of V_Z (pulse method).

c) Circuit description and requirements

G is a pulse current generator.

A is a peak-reading ammeter.

V is a peak-reading voltmeter.

The voltmeter V should have a high resistance compared with the differential resistance of the diode at the working voltage.

d) Measurement procedure

The temperature is set to the specified value.

The output of the pulse generator is increased until the specified working current is indicated on the ammeter. The working voltage across the diode is then read from the voltmeter.

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- working current (I_Z);
- pulse width and duty cycle of pulses (t_p, δ), preferably: t_p = 300 µs, $\delta \leq 2\%$.

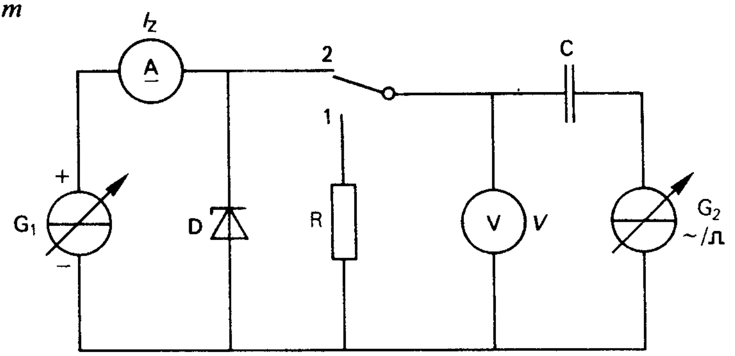
2. **Differential resistance** r_z

2.1 *Differential resistance within the working voltage range* r_z *(d.c. method)*

a) Purpose

To measure the differential resistance at a specified working current.

b) Circuit diagram



D = diode being measured

FIG. 19. — Circuit diagram for the measurement of r_z (d.c. method).

c) Circuit description and requirements

V is an r.m.s. or peak-reading voltmeter.

C is a blocking capacitor.

G_2 is an alternating or pulse-current generator.

The voltmeter impedance should be high compared with the differential resistance being measured.

The r.m.s. value of the alternating current should not be greater than 10% of the direct working current value; alternatively, for a pulse current generator, the peak-to-peak value should not exceed 30% of the direct working current value. R should be approximately equal to the differential resistance of the diode.

d) Measurement procedure

The temperature is set to the specified value.

The direct current generator is adjusted to give the specified value of the working current I_Z.

With the switch in position 1, the constant current generator is adjusted until the reading of the voltmeter is:

$$V_1 = R\, I_z$$

where:

I_z is the r.m.s. value of the specified small-signal alternating current (e.g. 10% of the direct working current).

With the switch in position 2, a second reading V_2 is obtained. The differential resistance is calculated using the expression:

$$r_z = \frac{V_2}{I_z} = \frac{V_2}{V_1} R$$

e) Specified conditions

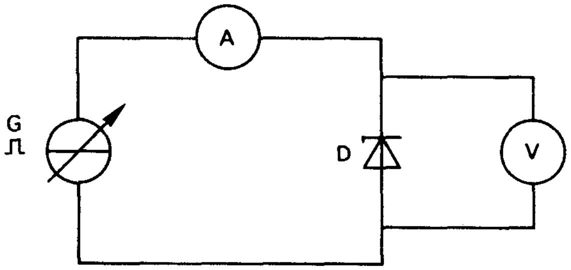
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- working current (I_Z);
- measurement frequency (if different from 1 kHz);
- mounting conditions including length of leads, if necessary.

2.2 *Differential resistance within the working voltage range r_z (pulse method)*

a) Purpose

To measure the differential resistance at a specified working current under pulse conditions.

b) Circuit diagram



D = diode being measured

FIG. 20. – Circuit diagram for the measurement of r_z (pulse method).

c) Circuit description and requirements

G is a pulse current generator.

A is a peak-reading ammeter.

V is a peak-reading voltmeter.

The working voltage V_Z is measured at two values of working current I_{ZL} and I_{ZH}, the average of which is the specified working current I_Z.

The difference between I_{ZL} and I_{ZH} should not exceed 30% of I_Z. However, since the voltage difference to be measured is small relative to the working voltage, an accurate high-impedance method of measuring voltage shall be used.

d) Measurement procedure

The temperature shall be accurately set to the specified value and controlled during the measurement.

The working voltage V_{ZL} is measured at the lower working current I_{ZL}. The working voltage V_{ZH} is measured at the higher working current I_{ZH}.

The differential resistance is calculated using the expression:

$$r_z = \frac{V_{ZH} - V_{ZL}}{I_{ZH} - I_{ZL}}$$

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- working current (I_Z);
- pulse width and duty cycle of pulses (t_p, δ), preferably: $t_p = 300\ \mu s$, $\delta \leqslant 2\%$.

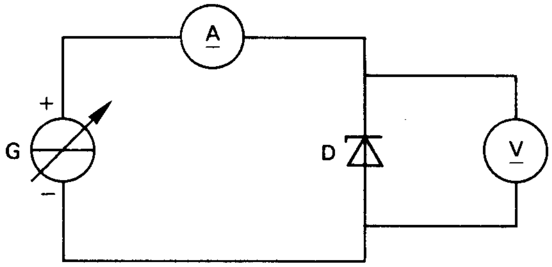
3. Temperature coefficient of working voltage α_{VZ}

3.1 *Temperature coefficient of working voltage α_{VZ} (d.c. method)*

a) Purpose

To measure the temperature coefficient of working voltage at a specified working current and over a specified temperature range.

b) Circuit diagram



D = diode being measured

FIG. 21. — Circuit diagram for the measurement of α_{VZ} (d.c. method).

c) Circuit description and requirements

The working voltage V_Z is measured at two specified temperatures T_1 and T_2.

However, since the voltage difference to be measured is small relative to the working voltage, an accurate high-impedance method of measuring voltage shall be used.

In addition, separate current-carrying and voltage-measuring contacts may need to be used.

d) Measurement procedure

For a specified working current I_Z as read from ammeter A, the working voltage is measured at two specified values of ambient, case or reference-point temperatures, T_1 and T_2, that shall be accurately set and controlled during the measurement.

The temperature coefficient is calculated using the expression:

$$\alpha_{VZ} = \frac{100(V_{Z2} - V_{Z1})}{(T_2 - T_1)V_{Z1}} \text{ (\% per degree Celsius)}$$

where:

V_{Z1} is the voltage measured at the lower temperature T_1, and

V_{Z2} is the voltage measured at the higher temperature T_2

e) Specified conditions

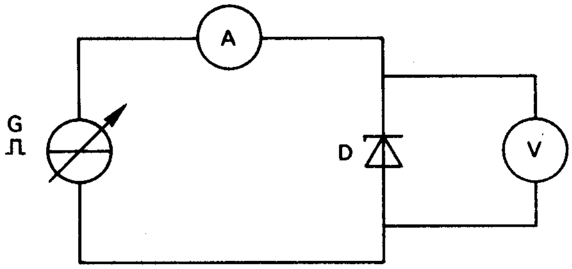
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- working current (I_Z);
- mounting conditions including length of leads, if necessary.

3.2 *Temperature coefficient of working voltage α_{VZ} (pulse method)*

a) Purpose

To measure the temperature coefficient of working voltage at a specified working current and over a specified temperature range, under pulse conditions.

b) Circuit diagram



D = diode being measured

FIG. 22. — Circuit diagram for the measurement of α_{VZ} (pulse method).

c) Circuit description and requirements

G is a pulse current generator.

A is a peak-reading ammeter.

V is a peak-reading voltmeter.

The working voltage V_Z is measured in accordance with the pulse method described in Sub-clause 1.2, at two specified temperatures T_1 and T_2.

However, since the voltage difference to be measured is small relative to the working voltage, an accurate high-impedance method of measuring voltage shall be used.

In addition, separate current-carrying and voltage-measuring contacts may need to be used.

d) Measurement procedure

For a specified working current I_Z as read from ammeter A, the working voltage is measured at two specified values of ambient, case or reference-point temperatures, T_1 and T_2, that must be accurately set and controlled during the measurement.

The temperature coefficient is calculated using the expression:

$$\alpha_{VZ} = \frac{100(V_{Z2} - V_{Z1})}{(T_2 - T_1)V_{Z1}} \text{ (\% per degree Celsius)}$$

where:

V_{Z1} is the voltage measured at the lower temperature T_1, and

V_{Z2} is the voltage measured at the higher temperature T_2

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- working current (I_Z);
- pulse width and duty cycle of pulses (t_p, δ), preferably: $t_p = 300$ µs, $\delta \leqslant 2\%$.

4. Reverse current I_R

The method for signal diodes in Section One, Clause 1, applies.

5. Forward voltage V_F

The method for signal diodes in Section One, Clause 2, applies.

6. Junction capacitance C_{tot}

The method for signal diodes in Section One, Clause 3, applies.

7. Noise voltage V_n

a) Principle of the method

The noise depends on the current I_Z of the diode. No simple correlation exists between the current I_Z and the noise voltage V_n (see for instance the curve in Figure 23).

The noise is amplified under stated conditions and measured with an r.m.s. voltmeter.

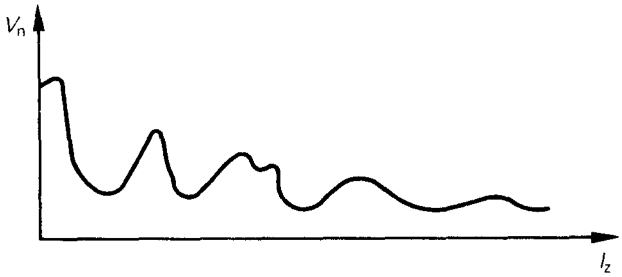
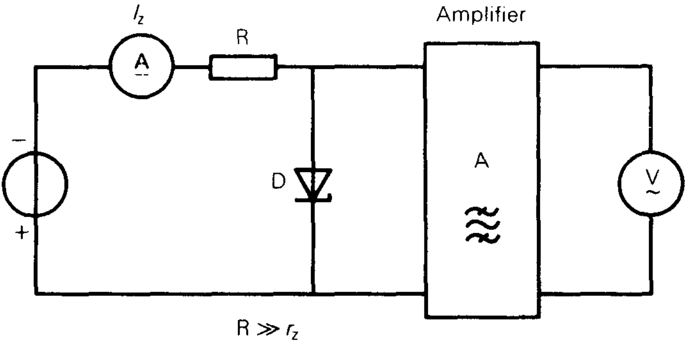


FIG. 23. — Noise voltage V_n as a function of I_Z.

b) Circuit diagram



D = diode being measured

FIG. 24. — Circuit diagram for the measurement of V_n.

c) Circuit description and requirements

The frequency band and the range of I_Z over which the measurement is made should be stated.

A is a selective amplifier having a stated bandwidth, a known amplification and a high-input impedance.

V is an r.m.s. voltmeter.

d) Precautions to be observed

If the inherent noise is not negligible, the measured value shall be corrected accordingly.

e) Specified conditions

- ambient or reference-point temperature (T_{amb} or T_{ref});
- current and frequency range of measurement (I_Z, f);
- noise detector bandwidth.

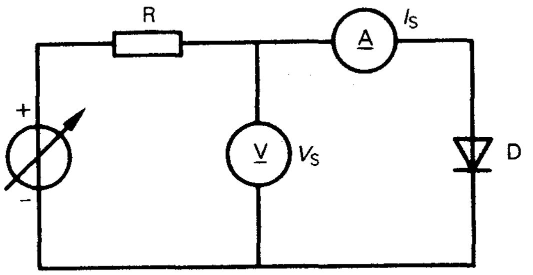
SECTION THREE — CURRENT-REGULATOR DIODES

1. Regulator current I_S

a) Purpose

To measure the regulator current of a current-regulator diode under specified regulator voltage.

b) Circuit diagram



D = current-regulator diode being measured.
R = resistor for current limiting (calibrated for pulse measurement only).

FIG. 25. — Circuit diagram for the measurement of I_S.

c) Circuit description and requirements

If a pulse measurement is required, the variable d.c. voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument, and the current is measured by a peak-reading voltmeter across the calibrated resistor R or with a current probe.

d) Measurement procedure

The temperature is set to the specified value.

The variable voltage generator is adjusted to obtain the specified value of regulator voltage V_S across the current-regulator diode.

The regulator current I_S is read from the ammeter A.

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- regulator voltage (V_S);
- pulse width (t_p) and duty cycle (δ) when a pulse measurement is specified.

2. Temperature coefficient of regulator current α_{IS}

a) Purpose

To measure the temperature coefficient of regulator current of a current-regulator diode under specified regulator voltage.

b) Circuit diagram

See Figure 25, page 41 .

c) Circuit description and requirements

If a pulse measurement is required, the variable d.c. voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument, and the current is measured by a peak-reading voltmeter across the calibrated resistor R or with a current probe.

The current measuring device A shall have a high accuracy, because the difference of the two currents to be measured occurs in the formula for the temperature coefficient. Therefore, the measuring device A shall be for example based on a bridge or compensation method or shall be a digital voltmeter of high precision.

The ambient, case or reference-point temperature shall be carefully controlled during the measurement. In the case of appreciable power dissipation within the device, thermal equilibrium shall be reached before the current measurements are made.

d) Measurement procedure

For a specified regulator voltage V_S as read from voltmeter V, the regulator current is measured at two specified values of ambient, case or reference-point temperatures T_1 and T_2.

The temperature coefficient is calculated using the expression:

$$\alpha_{IS} = \frac{100(I_{S2} - I_{S1})}{(T_2 - T_1)\ I_{S1}} \text{ (\% per degree Celsius)}$$

where:

I_{S1} is the current measured at the lower temperature T_1

I_{S2} is the current measured at the higher temperature T_2

e) Specified conditions

- ambient, case or reference-point temperatures (T_1 and T_2) (T_{amb}, T_{case}, T_{ref});
- regulator voltage (V_S);
- pulse width (t_p) and duty cycle (δ) when a pulse measurement is specified.

3. Regulator current variation

a) Purpose

To measure the regulator current variation of a current-regulator diode under specified regulator voltage.

b) Circuit diagram

See Figure 25.

c) Circuit description and requirements

If a pulse measurement is required, the variable d.c. voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument, and the current is measured by a peak-reading voltmeter across the calibrated resistor R or with a current probe.

d) Measurement procedure

The variable voltage generator is adjusted to the lower specified value V_{S1}; the regulator current I_{S1} is read from the ammeter A.

The variable voltage generator is adjusted to the higher specified value V_{S2}; the regulator current I_{S2} is read from the ammeter A.

The regulator current variation is then calculated using the expression:

$$\Delta I_S = I_{S2} - I_{S1}$$

e) Specified conditions

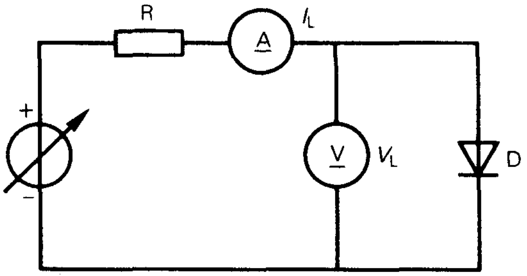
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- regulator voltages (V_{S1} and V_{S2});
- pulse width (t_p) and duty cycle (δ) when a pulse measurement is specified.

4. **Limiting voltage V_L**

a) Purpose

To measure the limiting voltage of a current-regulator diode under specified regulator current.

b) Circuit diagram



D = current-regulator diode being measured.

R = resistor for current limiting (calibrated for pulse measurement only).

FIG. 26. — Circuit diagram for the measurement of V_L.

c) Circuit description and requirements

If a pulse measurement is required, the variable d.c. voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument, and the current is measured by a peak-reading voltmeter across the calibrated resistor R or with a current probe.

d) Measurement procedure

The temperature is set to the specified value.

The variable voltage generator is adjusted to obtain the specified value of current I_L through the current regulator diode.

The limiting voltage V_L is read from the voltmeter V.

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- limiting current (I_L);
- pulse width (t_p) and duty cycle (δ) when a pulse measurement is specified.

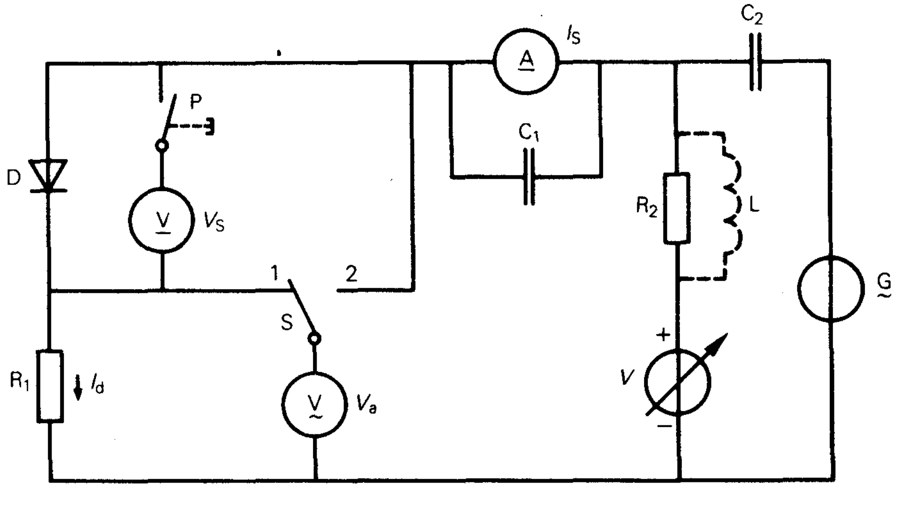
5. Small-signal regulator conductance g_s

5.1 *Two-voltmeter method*

a) Purpose

To measure the small-signal regulator conductance of a current-regulator diode under specified regulator voltage.

b) Circuit diagram



D = current-regulator diode being measured

FIG. 27. — Circuit diagram for the measurement of g_s (two-voltmeter method).

c) Circuit description and requirements

R_1 The value of this resistor shall be sufficiently low with respect to $1/g_s$; in practice, a value of 10 to 100 Ω will be used, depending on the voltmeter sensitivity.

R_2 The value of this resistor shall be sufficiently high with respect to the generator resistance.

L The inductance is optional; its use facilitates the adjustment of the specified operating point.

C_1, C_2 These capacitances shall represent an effective short-circuit at the measurement frequency.

P The push-button switch shall only be used for measuring V_S.

V_a The voltmeter shall have sufficient sensitivity; for the measurement of low inductances, it shall preferably be a selective instrument.

d) Measurement procedure

The temperature is set to the specified value.

The variable voltage generator G is adjusted to obtain the specified continuous voltage V_S across the current-regulator diode.

With the switch S in position 1, the value $V_1 = I_d R_1$ is measured on voltmeter V_a, while with the switch S in position 2, the value $V_2 = V_s + I_d R_1$ is measured, where V_s is the a.c. voltage drop across the current-regulator diode.

$$V_2 - V_1 = V_s$$

$$I_d = \frac{V_1}{R_1}$$

The small-signal conductance g_s is then calculated using the following expression:

$$g_s = \frac{V_1}{R_1\ (V_2 - V_1)}$$

For $V_2 \gg V_1$:

$$g_s \approx \frac{V_1}{R_1\ V_2}$$

e) Specified conditions

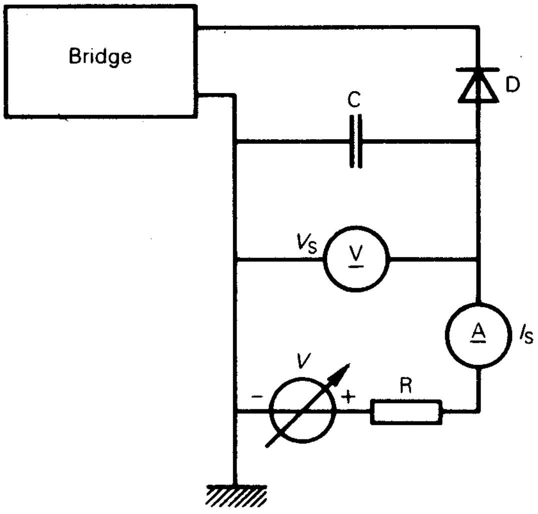
- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- regulator voltage (V_S);
- frequency of measurement (f).

5.2 *Two-terminal bridge method*

a) Purpose

To measure the small-signal regulator conductance of a current-regulator diode under specified regulator voltage.

b) Circuit diagram



D = current-regulator diode being measured

FIG. 28. — Circuit diagram for the measurement of g_s (two-terminal bridge method).

c) Circuit description and requirements

The bridge shall have a low d.c. resistance between its input terminals and shall be able to carry the required current without affecting the accuracy of the measurement.

Capacitance C shall provide an effective short-circuit at the frequency of measurement.

d) Measurement procedure

The temperature is set to the specified value.

The bridge is first balanced with the current-regulator diode removed.

The device being measured is inserted into the measurement socket and, with the specified regulator voltage applied, the bridge is again balanced.

g_s is then read from the bridge.

e) Specified conditions

- ambient, case or reference-point temperature (T_{amb}, T_{case}, T_{ref});
- regulator voltage (V_S);
- frequency of measurement (f).

6. Knee conductance g_k

The same measuring method as in Clause 5 above for small-signal conductance can be used, with the regulator voltage set to the specified value of V_K.

CHAPTER V: ACCEPTANCE AND RELIABILITY

SECTION ONE — ELECTRICAL ENDURANCE TESTS

1. General requirements

Clause 2 of Publication 747-1, Chapter VIII, Section Three, which has the same title, applies.

2. Specific requirements

2.1 *List of endurance tests*

A choice of endurance tests is given in Table II, which are applicable for all sub-categories of diodes.

2.2 *Conditions for endurance tests*

Test conditions and test circuits are listed in Table II. The relevant specification will state which test(s) will apply.

2.3 *Failure-defining characteristics and failure criteria for acceptance tests*

Failure-defining characteristics, their failure criteria and measurement conditions are listed in Table I.

Note. — Characteristics shall be measured in the sequence in which they are listed in this table, because the changes of characteristics caused by some failure mechanisms may be wholly or partially masked by the influence of other measurements.

2.4 *Failure-defining characteristics and failure criteria for reliability tests*

Under consideration.

2.5 *Procedure in case of a testing error*

When a device has failed as a result of a testing error (such as a test equipment fault or measurement equipment fault, or an operator error), the failure shall be noted in a data record with an explanation of the cause.

TABLE I

Failure-defining characteristics for acceptance after endurance tests

Device sub-categories	Failure-defining characteristics	Failure criteria (Note 1)	Measurement conditions
Signal diodes	I_R	> 2 x USL	Highest V_R specified for I_R (Note 4)
	V_F	> 1.1 x USL	Highest I_F specified for V_F
Voltage-reference diodes	I_R	> 2 x USL	Highest V_R specified for I_R
	V_Z	|Δ|> 1% of IVD (Note 2) |Δ| > 2% of IVD (Note 3)	I_Z specified for nominal V_Z
	r_z	> 1.2 x USL	
	V_{nz}	> 1.5 x USL	See the relevant specification
Voltage-regulator diodes	I_R	> 2 x USL	Highest V_R specified for I_R
	V_Z	> USL < LSL	I_Z specified for nominal V_Z
	r_z	> 1.2 x USL	

Notes 1. — USL = upper specification limit
LSL = lower specification limit
IVD = initial value of individual device

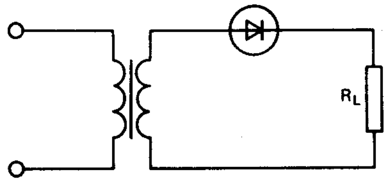
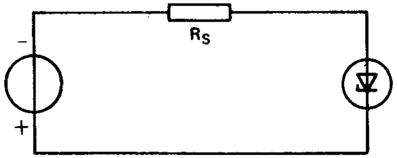
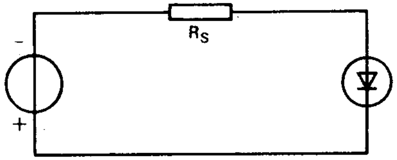
2. — For devices which are specified with a tolerance less than or equal to 1%.

3. — For devices which are specified with a tolerance greater than 1%.

4. — Where the V_R specified for I_R measurements is in the breakdown region, a lower value of V_R may be used.

TABLE II

Conditions for the endurance tests

Device sub-categories	Tests	Operating conditions			Test circuits	Remarks
		Current	Voltage	Temperature		
Signal diodes	Operating life	Equivalent to a value which gives power dissipation P_{tot}max. or maximum specified average rectified current	Sine wave 50 Hz or 60 Hz. Peak value = $V_R$max.	(See Sub-clause 2.1.3 of 747-1, Chapter VIII, Section Three)		R_L = load resistor
	High-temperature reverse bias		V_R = $V_R$max.	Highest operating temperature, at which V_R applies at T_{amb}max. or T_{case}max. as specified		R_S = current-limiting resistor
Voltage-reference diodes and voltage-regulator diodes	Operating life	$I_Z$max. as given in the relevant specification	Depends on I_Z	(See Sub-clause 2.1.3 of 747-1, Chapter VIII, Section Three)		R_S = current-limiting resistor $R_S \geq 0.2\frac{V_Z}{I_Z}$

AMENDMENT NO. 1

Page 4

CHAPTER II – TERMINOLOGY AND LETTER SYMBOLS

SECTION ONE – SIGNAL DIODES (INCLUDING SWITCHING DIODES)

Replace, on page 6, the existing subclause 2.4.3 by the following new subclause:

2.4.3 *Forward recovery time* t_{fr} (of a rectifier diode or signal diode)

The time interval between the instant when the forward voltage rises through a specified first value and the instant when it falls from its peak value V_{FRM} to a specified second value close to the final stable value of forward voltage (specification method A as shown in figure 29), or when the extrapolated forward voltage reaches zero (specification method B as shown in figure 30), upon the application of a specified step of forward current following a zero-voltage or other specified reverse-voltage condition.

NOTES

1 The specified first and second values referred to in the definition are usually 10 % and 110 %, respectively, of the final stable value (V_F^* in figures 29 and 30).

2 The extrapolation is carried out with respect to specified points A and B as shown in generalized form in figure 30.

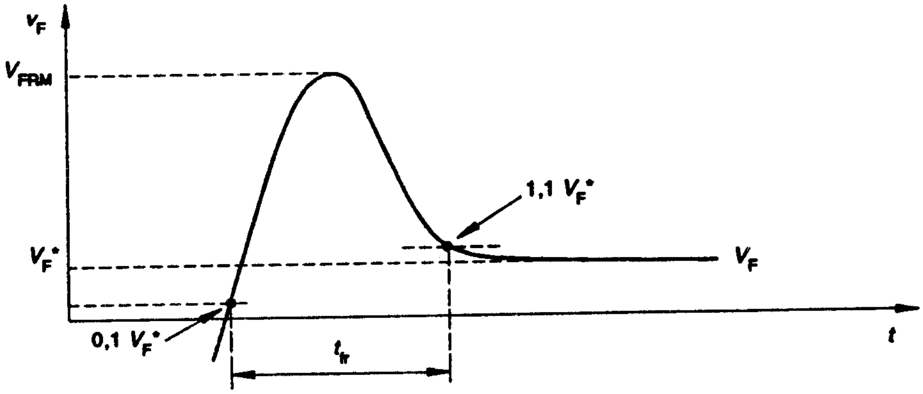


Figure 29 – Forward recovery time, specification method A

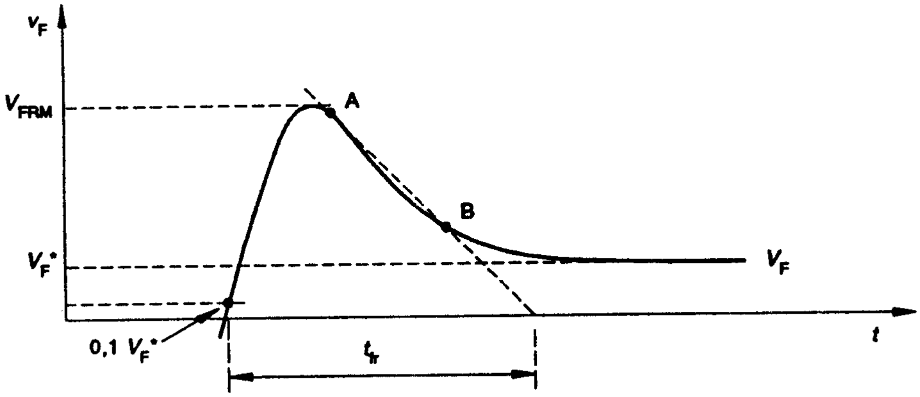


Figure 30 – Forward recovery time, specification method B

Page 9

SECTION TWO – VOLTAGE-REFERENCE DIODES AND VOLTAGE-REGULATOR DIODES

Replace the existing subclauses 1.3 and 1.4 by the following new subclauses:

1.3 *Forward direction*

The direction of current that results when the P-type semiconductor region connected to one terminal is at a positive potential relative to the N-type region connected to the other terminal.

NOTE - If temperature-compensation diodes are included, these are ignored in the determination of forward direction.

1.4 *Reverse direction*

The direction of current that results when the N-type semiconductor region connected to one terminal is at a positive potential relative to the P-type region connected to the other terminal.

NOTE - If temperature-compensation diodes are included, these are ignored in the determination of reverse direction.

Page 10

SECTION THREE – CURRENT-REGULATOR DIODES

Replace the existing subclause 1.2 by the following new subclause:

1.2 *Anode terminal*

See Publication 747-1, chapter IV, subclause 3.5.

Page 11

Replace the existing subclause 1.3 by the following new subclause:

1.3 *Cathode terminal*

See Publication 747-1, chapter IV, subclause 3.6.

Page 20

CHAPTER IV: MEASURING METHODS

SECTION ONE – SIGNAL DIODES (INCLUDING SWITCHING DIODES)

Replace, on page 23, the existing subclause 4.1 by the following new subclause:

4.1 *Forward recovery time t_{fr} and peak forward recovery voltage V_{FRM}*

a) *Purpose*

To measure the forward recovery time and the peak forward recovery voltage of the diode.

b) *Circuit diagram and test waveforms*

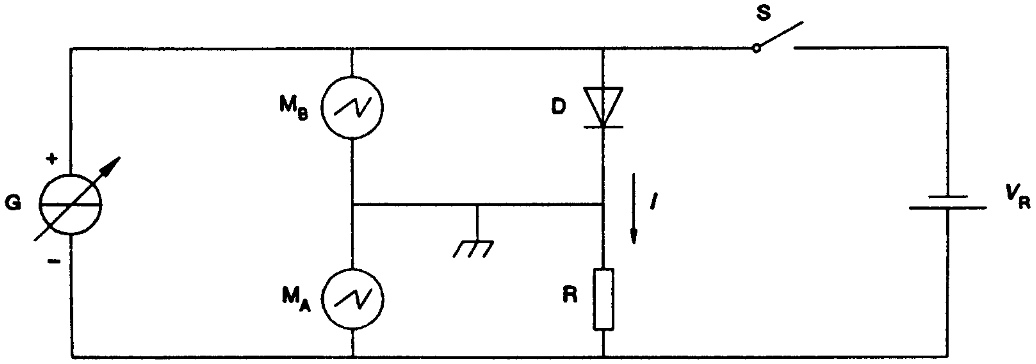


Figure 31 – Circuit diagram

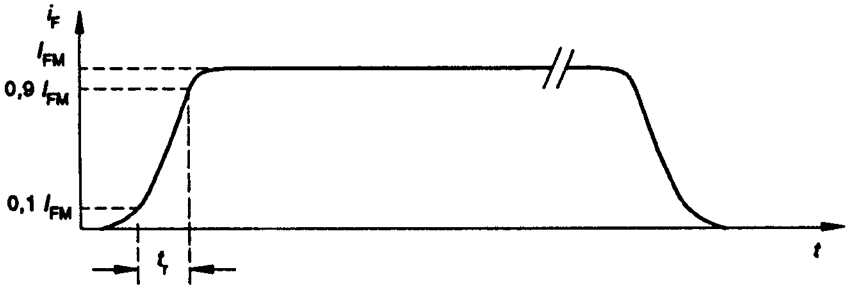


Figure 32a) – Current waveform

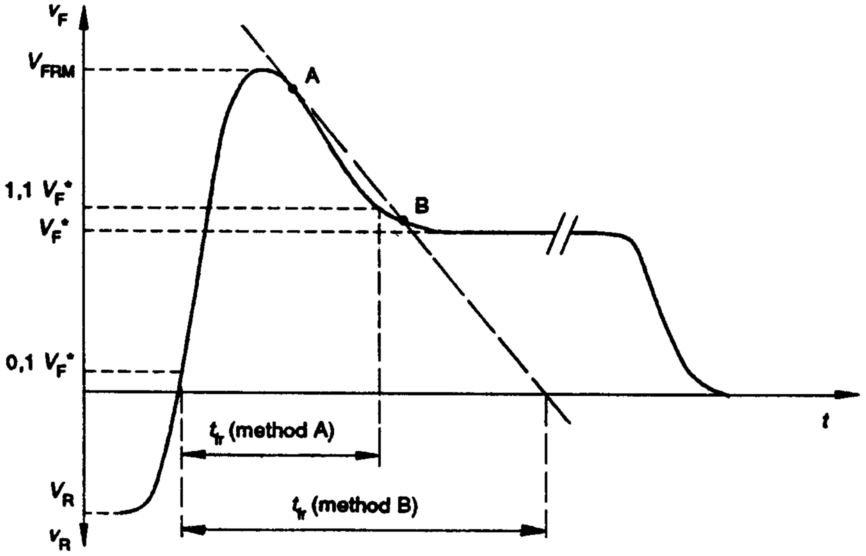


Figure 32b) – Voltage waveform

Figure 32 – Current and voltage waveforms

c) *Circuit description and requirements*

D = diode being measured.

G = current-pulse generator having a compliance voltage (open-circuit output voltage) of 50 volts minimum or three times V_{FRM}, whichever is greater.

R = non-inductive calibrated resistor.

S = electronic switch, which is closed except for a period starting just before the current pulse and throughout its duration.

M_A and M_B = oscilloscopes or other monitoring instruments.

The pulse duration shall be long enough for the forward voltage to have reached the stable value V_F^*.

The pulse duration and the duty cycle of the current-pulse generator should be such that negligible internal heating of the diode occurs.

d) *Measurement procedure*

The temperature is set to the specified value.

While monitoring the current waveform on M_A, the current-pulse source is adjusted to the specified conditions of rise time t_r and forward current I_{FM}.

The reverse voltage V_R is adjusted to the specified value, and switch S is appropriately set.

The peak forward recovery voltage V_{FRM} and the forward recovery time t_{fr} are measured on the waveform of voltage across the diode on M_B in accordance with the applied specification method.

e) *Specified conditions*

- ambient or case temperature (T_{amb}, T_{case});
- peak forward current (I_{FM});
- rise time of current pulse (t_r) (between 10 % and 90 % of I_{FM}, unless otherwise stated);
- voltages defining beginning and end of the forward recovery time, if different from 10 % and 110 %, respectively, of V_F^*.
- reverse voltage (V_R).

AMENDMENT NO. 2

Page 4

CHAPTER II: TERMINOLOGY AND LETTER SYMBOLS

Section two: Voltage reference diodes and voltage-regulator diodes

Replace, on page 9 *, clause 2 by the following new clause 2:*

2 Terms related to ratings and characteristics

The relevant terms and definitions given in IEC 747-1, chapter IV, clause 5, apply

Additional terms and definitions are given below.

2.1 **regulating range:** The range of currents within which the voltage is maintained between specified limits.

2.2 **working current** I_Z: A current within the regulating range.

2.3 **working voltage** V_Z: A voltage within the regulating range.

2.4 **working voltage range** V_Z **(specific term):** The range of working voltages for a specified range of working currents, under specified measuring conditions (see notes).

NOTES

1 The measuring conditions may be:

a) measurement after thermal equilibrium has been reached with either T_{case} specified or T_{amb} and mounting details specified (d.c. method described in chapter IV, section two, 1.1);

b) measurement at a specified junction temperature (pulse method described in chapter IV, section two, 1.2).

2 Measuring conditions a) are preferred.

2.5 **differential working resistance** r_z: The differential resistance at a working current within the regulating range.

2.6 **(mean) temperature coefficient of working voltage** α_{VZ}: The quotient of:

- the change in working voltage between two specified values of temperatures, by

- the difference between these two temperatures,

for a specified working current and under specified measuring conditions (see notes).

NOTES

1 See note 1 to 2.4.

2 Measuring conditions b) are preferred.

3 The change in working voltage is usually expressed as a percentage of working voltage.

2.7 **working voltage drift** $\Delta V_{Z(t)}$: The drift of the working voltage for a specified value of working current, under specified measuring conditions (see notes).

NOTES

1 See note 1 to 2.4.

2 Measuring conditions b) are preferred.

Page 10

3.3 *Additional list of letter symbols*

In the table, under 3.3.3, replace Differential resistance within the working voltage range *by* Differential (working) resistance *and replace* Working voltage long-term instability *by* Working voltage drift $\Delta V_{Z(t)}$.

Page 14

CHAPTER III: ESSENTIAL RATINGS AND CHARACTERISTICS

Section one: Signal diodes (including switching diodes)

Replace, on page 16, subclause 3.4.3 by the following new subclause:

3.4.3 *Forward recovery time (t_{fr}) (where appropriate)*

Maximum value, under the following specified conditions:

a) virtual junction temperature (T_{vj});

b) peak forward current (I_{FM});

c) rise time of the forward current pulse (t_r), between 10 % and 90 % of I_{FM};

d) minimum compliance (open-circuit) voltage of pulse source, preferably three times V_{FM};

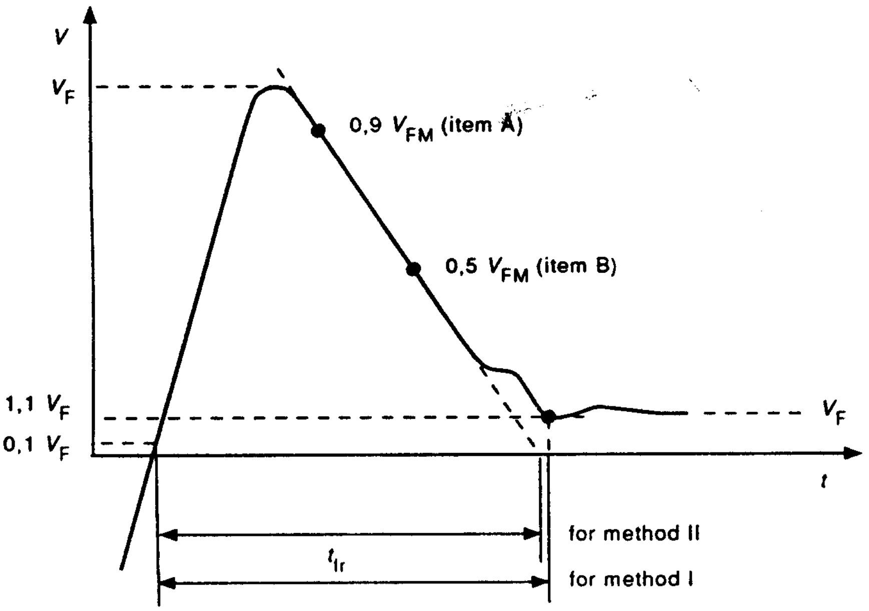
e) voltage defining the beginning of t_{fr}, preferably 10 % of the final stable value of forward voltage (V_F);

f) for specification method I: voltage defining the end of t_{fr}, preferably 110 % of V_F;

g) for specification method II: voltages defining points A and B for the extrapolation, preferably 90 % and 50 % of V_{FM}, respectively;

h) reverse voltage (V_R, preferably $V_R = 0$).

NOTE - Regarding conditions e), f) and g) see the definition of t_{fr} in chapter II.



V_F = steady-state forward voltage

t_{fr} = forward recovery time

Figure 29 – Voltage waveform during forward recovery

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